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Design and Evaluation of Engineering Curricula Learning Outcomes

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The authors consider the design techniques in engineering curricula (EC) based on improved ABET double-loop model. Within its framework the design and planning of complex learning outcome evaluation focused on correlation between EC and international standards in engineering education have been suggested.

Key words: *engineering education, competence-based approach, educational standard, educational program, learning outcomes, evaluation.*

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Introduction

Content of engineering education is to provide the competitiveness of the graduates in not only inner-Russian labour market but also in the international one. For this purpose the basic educational programs (BEP) of Tomsk Polytechnic University (TPU) are focused on the current international (EUR-ACE, ABET, Washington Accord, CDIO) and state (RF HPE FSES) standards in engineering education and designed in accordance with the double-loop model of ABET [1]. The model defines the sequence of design and evaluation stages in BEP quality as well as relates the inner-university quality processes in training engineers to the environment. However, methodological bases for design and evaluation of BEP complex learning outcomes (LO) presented by graduates' professional and cross-cultural competencies have been poorly studied.

In the given article the design and evaluation technique for BEP LO is suggested, the principles of their decomposition, requirements for LO and their components based on the improved BEP design double-loop model are put forward.

Design of the Basic Educational Program of Tomsk Polytechnic University

BEP TPU design technique is based on the double-loop model (Fig. 1) [2, p. 26–28].

The external (left) loop presents the processes of formation, evaluation and correction (if necessary) BEP goals. The internal (right) loop shows the way in which BEP LO are planned, achieved and evaluated in the university.

The interconnection of internal and external loops demonstrates that achievement of BEP goals is verified through LO evaluation. «Achievement» in external loop is performed slower than it is in the internal one as only on the expiry of a definite period from the moment of finishing training in curriculum (3–5 years) one can evaluate the BEP goal achievement and customers' satisfaction to the full extent, and, if necessary, correct the curriculum goals and BEP LO [2, p. 26–28].

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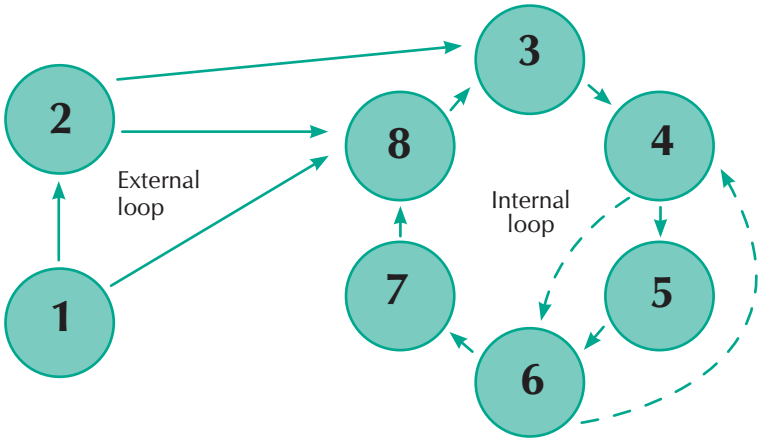
Fig. 1. Double-loop Model of BEP Designing and Performance [2, p. 27]

1 – educational program requirements; 2 – educational program goals; 3 - outcomes; 4 – ways and means of their achievements; 5 – ways and means of evaluation; 6 – evaluation indicators; 7 – academic process organization; 8 – outcome and goal achievement evaluation

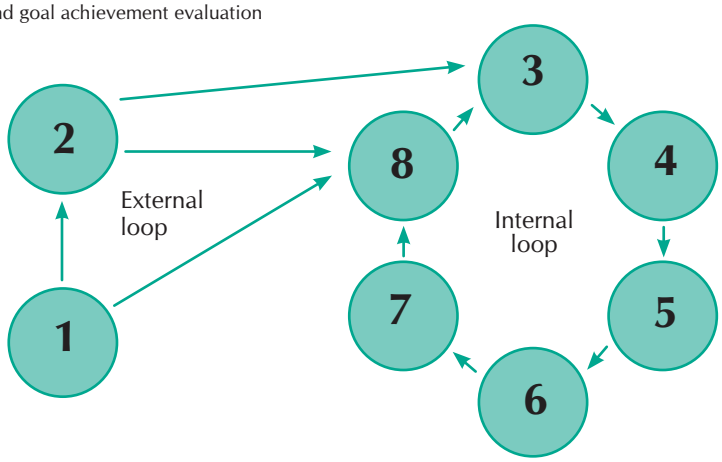


The current experience in BEP design and performance in TPU has shown that this model requires re-designing for the internal (university) loop (Fig. 2). This solution will be illustrated by the concrete example below.

In the improved model the mutual replacement of indicator design procedure and choice of evaluation means to perform procedure and training facility development is performed. The indicators, criteria, means, and methods of complex LO evaluation determined at the initial BEP design stage can be considered as LO quality standards, which curriculum, syllabus, and educational technologies should be focused on. This would allow all participants of academic process to have a common idea of LO, their intermediate representation set by evaluation indicators and distributed among the evaluation procedures of complex LO (course projects, internships, student's research, graduate qualification work). In our opinion, evaluation indicators can be referred to as intermediate qualification grades that can be proved at the evaluation procedures arranged together with potential employers. In this case they should pass through the proce-

Fig. 2. Improved Double-Loop Model of BEP Design and Performance [3, p. 33]

1 – educational program requirements; 2 – educational program goals; 3 - outcomes; 4 – ways and means of their achievement; 5 – ways and means of evaluation; 6 – evaluation indicators; 7 – academic process organization; 8 – outcome and goal achievement evaluation



dure of the preliminary agreement with employers. Then, special attention is paid to 3, 4 and 5 elements of the internal model loop.

Design and Evaluation of BEP Learning Outcomes

In the work [2, p. 13-15] learning outcomes of BEP are referred to as professional and universal (cross-cultural) competencies developed by the graduates by completing the curriculum of the definite profile and level. The necessary stage in BEP LO design, according to [2, 3], is their decomposition into components (Learning Outcome Components) – academic performance, qualifications and practical skills. Decomposed LO (local results, LR) make more specific training profile (speciality), define education content, training and evaluation methods, as well as set the level of intermediate LO performance.

At present BEP developed in TPU of two-level training system form no more than 12-18 LO by the time of graduation, including state and international standard requirements that, in their turn, are decomposed into local results in the form of academic performance, skills and qualifications acquired in academic training (Fig. 3).

Technique of LO design and evaluation, based on requirements of state and international standards, is presented in Fig. 4. Full line defines the main sequence of stages, dashed line – sequence of stages that is performed at discrepancies.

At the first Stage the initial data for planning LO BEP (FSES requirements, Criterion 5 of AEER, requirements of IEA Graduate Attributes and Professional Competencies, EUR-ACE Framework Standards, CDIO Syllabus, specific requirements of strategic partners, requirements of local, national, and international labour markets) are defined.

At the second Stage the basis for requirement classification for LO is to be chosen (professional tasks, Criterion 5 of AEER, CDIO Syllabus). At the third Stage LO are formulated. At the fourth Stage LO are analyzed with respect to doubling, accordance with requirements set up for LO. At the fifth Stage decomposition of LO into components is performed (FSES cross-cultural and professional competencies are taken as a basis for decomposition). At the sixth Stage LR are analyzed to avoid doubling and evaluation of requirement correspondence specified for LR. At the seventh Stage the repeated analysis of LO definitions is made in view of their components. At the eighth Stage for each LO from three to six evaluation indicators are developed. At the ninth Stage the list of evaluation criteria is defined for the developed evaluation indicators. At the tenth Stage the compliance matrix of LO, their indicators and evaluation methods is built.

The experience in LO design has permitted the authors to form the list of requirement for LO and their components (LR) to provide transparency and succession of training levels (Bachelor Degree, Specialist Degree, Master Degree), uniform understanding of LO by all interested participants of academic process as well as monitoring of TPU BEP LO quality.

Each LO has terse and expanded language as it is formulated in the language of competencies [4, p.19-21]. Terse language comprises (groups) the requirements for FSES learning outcomes, strategic partners, or concerned parties' demands into clusters based on definite achievement in the professional sphere.

Fig. 3. Formation and Presentation of BEP Learning Outcomes

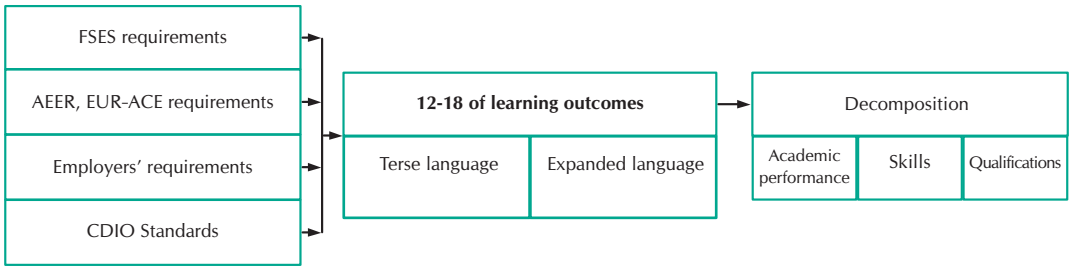
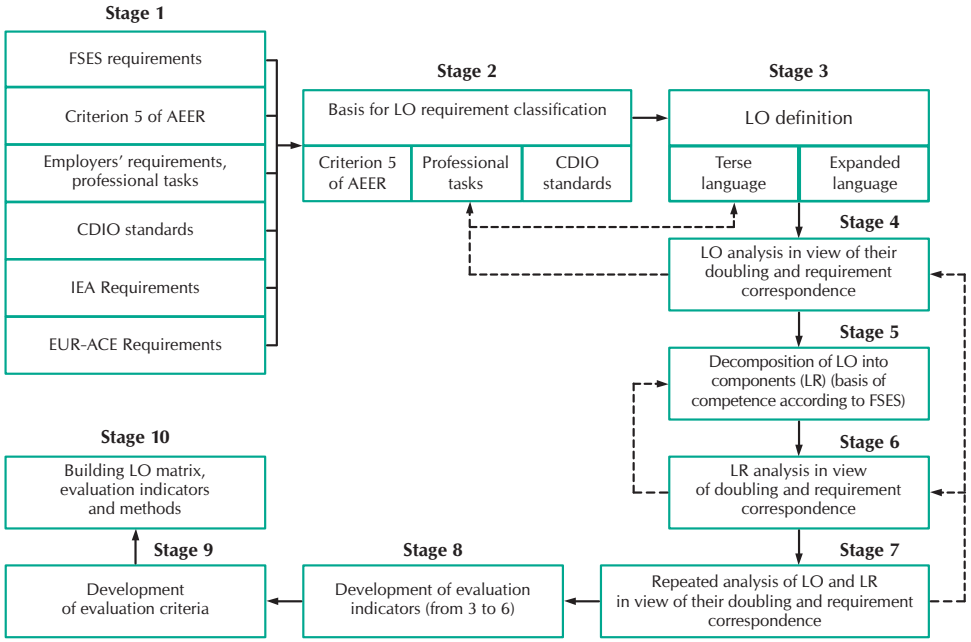


Fig. 4. Technique of Design and Decomposition of BEP LO



Expanded language has a declarative definition making concrete the activity (action) with verbs (not more than 3) that are in the spotlight at evaluation.

BEP LO develop all competencies from the list of FSES requirements, in this case, in the course of one outcome both cross-cultural and professional competencies can be formed. One FSES competence can correspond to several LO, but its components (LR) cannot double for different BEP LO.

BEP LOs are complex results and achieved in the course of mastering some didactic units – modules (disciplines) of BEP, therefore they can be objectively evaluated only by complex methods (graduate qualification paper/Master's thesis/diploma project, interdisciplinary examination, course project, research work, internship). LR evaluation with subsequent generalization of obtained results does not replace BEP LO.

LRs define definite student's activity (abilities) expressed in the language of engineering problems with the view of training profile, with characteristic of achievement quality if applicable («independently», «efficiently», «exactly» etc.).

For one LO not more than 6-10 LRs are defined, that are distributed in the following way, at the level: academic performance (awareness of facts, principles, theories and practices relevant to the professional and academic spheres of activity) – 3-4 LRs; skills (proved / shown), abilities in applying knowledge in professional problem solutions and tasks) – 2-3 LRs; qualifications (repeatedly proved abilities / skills in successful solution of problems in professional or other spheres) – 1-3 LRs.

LRs are to be feasible (achievable) and based on one of the evaluation methods in the course or by the time of the course completion. For LRs a single writing form is used: it is written in the form of concise declarative sentence, third person and directly concerned with student's activity (presented in one verb which evaluation is focused on). Duplication (repetition) and inclusion of LR in the course of the entire decomposition are to be excluded (the most significant components are distinguished, but doubling or parts of other components are excluded). LRs are not the results of learning only one discipline.

The next stage in BEP LO design is planning achievement indicators and LO evaluation criteria as well as choice of evaluation tools. LO achievement indicators, along with evaluation criteria are to anticipate the rate of work performance shown by student / graduate by the time of evaluation [4, p.19-21]. Achievement indicators (not more than 3-6 per one LO [4]) are formulated in the form of a short declarative sentence. Evaluation criterion can be defined for both separate indicator and the whole BEP LO achievement indicator group. Evaluation criteria characterize the quality of work performed (either minimal or rated).

Achievement criteria are conditions resulting from definition of competence. According to the definition, competence [4, p.19-21] includes three constituents: commitment, capacity and conditions. Each of the constituents, in its turn, can have a number of attributes. It is desirable to be restricted by three attributes, the most essential from the view point of learning outcomes (Fig. 5).

At evaluating conditions of definite problem solutions concerned with designing engineering projects and systems, performance of applied research, production practical activity it is important to determine the rate of novelty for the problem solved, level of students' autonomy and rate of resource loading for solution of the problem set. Students' competence evaluation would be even higher if the rate of problem novelty and the level of students' autonomy in problem solution would higher and the rate of initial resource loading would be lower, that would promote students to compensate for the deficiency by themselves. Successful solution of the problem in more difficult conditions indicates higher level of students' proficiency [5].

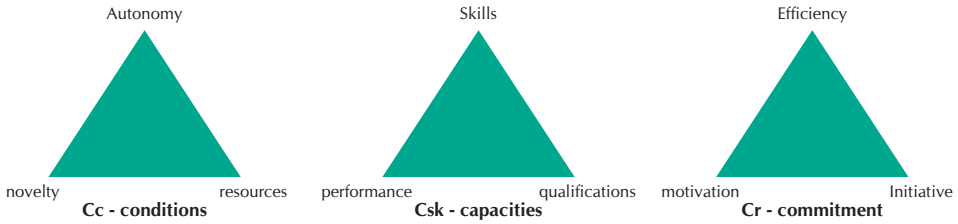
At evaluating the capacities demonstrated by the students in solution of practical problems the rate of academic performance attained, the level of skills developed and qualifications in application of academic performance and skills. Students' commitment for problem solution is evaluated in terms of their motivation that is demonstrated in the form of students' activity and interest in obtaining results, efficiency and initiative of their actions in problem solution [5].

After LO having been defined, their components (LR), evaluation indicators, criteria, and methods having been determined, in other words, having answered the questions «WHAT WAY?», «WHEN?» and «HOW?» LO will be evaluated, one can start to definition of academic content, techniques and methods. Therefore, we consider the suggested re-designing of internal cycle of BEP two loop design model to be essential and reasonable.

Conclusion

Предложена технология проектироваThe technique in designing and evaluating learning outcomes of engineering educational programs has been suggested. The technique includes several stages that allow the design team to enhance the quality of the designed BEP and provide a graduates' competitiveness. Besides, the list of requirements for the outcomes and their components has been formed. It was shown that in BEP designing, preliminarily set learning outcomes by means of evaluation indicators and criteria, have to be taken into account together with the requirements of educational and professional standards in choosing educational techniques, methods, and learning tools, content of academic aids and designed evaluation resources.

Fig. 5. Criterion Features in Terms of Competence Components



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